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# ENHANCEMENT OF THE SINGLE POINT POSITIONING ACCURACY (USING THE OBSERVATIONS OF IGS SERVICE)

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## ABSTRACT

This research tends to improve the GPS Absolute Point Positioning (APP) accuracy by using the daily observations for the nearest station of International GPS Service network 'called DRAG station' and solving its observations data differentially with the observations data of any unknown points in the studied area in EGYPT. But, there is a main problem; because the DRAG station located at a distance about 660km from the studied points which leads to the impossibility of eliminating the ionospheric error and orbital error with differential processing. Therefore, the resultant positioning accuracy was low, it is about 2.5m. To overcome the previous problem and errors, the data is processed as follows : firstly, observing a fixed point in the studied area at a distance between it and the unknown point less than 20km, and solving its observations relative to the DRAG station observations by using the triple difference technique ; secondly, estimating the change in ionospheric error from the previous step after using the precise ephemeris data to adjust the orbital errors ; finally, estimating the unknown point coordinates by solving their observations relative to the DRAG station observations by a triple difference technique with using the precise ephemeris data and the previous estimated value of change in ionospheric error. It is found that this adjusting process enhances the improvement of the positioning accuracy, about 30 cm , if the interval period between observing the fixed and unknown point is less than 100 min.

**KEYWORDS:** GPS, Absolute Point Positioning, Phase Measurements, IGS Service, Triple Difference .

## INTRODUCTION

There are several sources of error that degrade the GPS position from few meters to tens of meters [1]. These sources of errors are orbital errors: ionospheric and tropospheric delays, satellite and receiver clock errors, multipath, biases, and cycle slip [2].

GPS positioning can be classified into two positioning techniques: absolute and differential positioning (Figure 1). The Absolute Point Positioning (APP) uses one unit receiver to determine the coordinate positioning; but due to the affected errors, this mode has a bad accuracy. In the differential GPS Positioning (DGPS), two or more receivers are used to measure the same satellites at the same time, where one receiver occupies and observes the known point (Base), and the other receiver occupies and observes the unknown point (Rover). The positioning coordinates of the unknown points are determined relative to the positioning coordinates of the base station; therefore most of the errors can be

reduced or eliminated through the differences processes. By this method, the accuracy can reach to centimeters for baseline less than 20 km [3, 4].

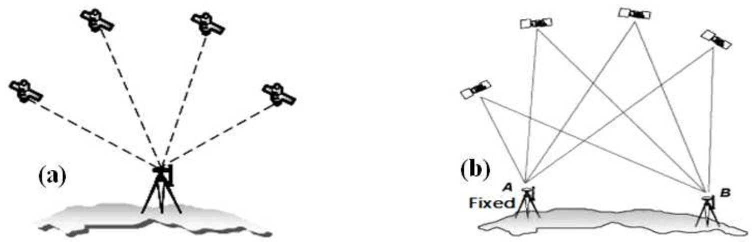


**Figure 1: GPS Positioning Techniques (a- APP Technique and b- DGPS Technique)**

Absolute Point Positioning (APP) is much economic and easier than DGPS, because it uses one unit receiver. According to the accuracy, it has two levels from positioning Service: Standard Point Positioning (SPP) and Precise Point Positioning (PPP) [5 and 6]. The first technique, SPP, uses the broadcast ephemeris data in estimating the receiver position [4, 7 and 8], where its accuracy is about 40m [9, and 10]. The second technique, PPP, was proposed for the first time in 1995 by Heroux and Kouba. It determines the position by processing un-differentiated dual frequency code and carrier-phase measurements from a dual-frequency receiver coupled with precise GPS orbit and clock products. It had been widely demonstrated that it is capable of providing a good positioning solutions at sub-decimeter level for kinematic positioning and at sub-centimeter level for static positioning; in condition of the range is free from ionospheric delay [3, 11, 12 and 13]. The precise products have been supplied by the International GPS Service (IGS) since 2000 [14].

Over the past fifteen years, a number of researchers and engineers had developed the Single Point Positioning technique and its applications. **Alkan. R. M. [2002]** had studied the variation in navigation coordinates without Selective Availability (SA) and the advantages of removing SA from single point in the positioning accuracy, where the accuracy in some position, from 15 to 25 meters, had been achieved [9]. **El-Rabbany [2002]** had presented a number of GPS point positioning approaches: firstly, by using the ionosphere-free code with the broadcast ephemeris, as the accuracy was about 10-15m; secondly, by using the ionosphere-free code with precise ephemeris and clocks, as the accuracy was about 5-10m; finally, by using the IGS network with final precise ephemeris and clocks, as the accuracy was little than 1m [3]. **Mosavi, M. R., et. al., [2013]** had estimated the receiver position by using Kalman Filter (KF) with pseudo-range data , carrier phase data and the combination of these with presenting the advantages and disadvantages of them . The accuracy achieved was 23.20m at KF code observable, 20.83m at KF phase observable and 12.52m at phase code observables [15]. **Chen, H. W., et al., [2013]** had used a new GPS positioning algorithm to improve the single point of positioning at short observation time, by combining the doppler and the code-phase measurements. The results which referred to the accuracy which equals 24 m for an observation time is about 1 minute, and the accuracy ranging from 10 to 20 m for an observation time equals 10 minute [10]. There was a study about DGPS by **Talaat, A., et al [2007]** that could serve this research, where it had studied the effect of the baseline length on the differential positioning accuracy, where the results referred to the accuracy which is about 5mm error / 1km length [14].

## GPS MEASUREMENTS

Basically, there are two kinds of measurements which can be used for positioning: code (also called pseudorange, or code pseudorange) and carrier phase. Both measurements are subject to ionospheric refraction errors, tropospheric refraction errors, the receiver clock error, the satellite clock error, multipath errors (caused by reflections) and random

measurement noise [16]. The equations of pseudorange and code pseudorange are as follows (Equ. 1 and 2) [17, 18]:

$$\boldsymbol{P_{L_i}(t)} = \rho(t) + c[\,\delta t_r(t) - \delta t_s(t)] + T(t) + I(t) + ER_t(t) + Mpath(t) + bias \quad \textbf{(1)}$$

$$\emptyset_{L_i}(\boldsymbol{t}) = \rho(t) + c[\,\delta t_r(t) - \delta t_s(t)] + \boldsymbol{\lambda_{L_i}}N + T(t) - I(t) + ER_t(t) + Mpath(t) + bias \quad \textbf{(2)}$$

Where **P** is the measured pseudorange (m); $\boldsymbol{\rho}$ is the true geometric range (m) ; **c** is the speed of light (m/s); **δtr** is the receiver clock error (s); **δts** is the satellite clock error (s); **T** is the tropospheric error (m); **I** is the tropospheric error (m); $\mathbf{ER_t}$ is the earth rotation error (m); **N** is integer ambiguity cycles; $\boldsymbol{\phi}$ is the measured phase obtained from observation RINEX file (cycle); $\mathbf{L_i}$ is the phase type $L_1$ or $L_2$ ; and **Mpath** is the multipath error (m) . But, in this research, the observing must be done in an open area, so 'Mpath' error is approximately zero.

Using the carrier phase measurement for position estimation is more accurate than using the code measurement [19], because the code measurement has high bias, but it can easily be used for positioning. Where the main problem at phase measurement is that ; it includes some whole cycles (integer ambiguity) plus a fraction of carrier phase, this integer ambiguity changes from observation session to another , this change has unknown value [15, 20].

**Collected Observation Data**

The observation data which is processed in this research is taken from master thesis work for a demonstrator in Mining and Metallurgy Department in Assiut University. The collected data are for 20 points at open area (El -Wady El- Assiuty) (Figure 2) observed by GPS receiver (ASHTECH A-12), where the real coordinates of these 20 points are determined by Differential GPS Positioning method (DGPS), as it is the most accurate positioning method . The observation conditions of the collected data are a mask angle = $12^o$: where the optimum value of the elevation mask angle is [21]; epoch interval= 1 sec; where the good interval is [22] and the occupation period = 20 min. But in applying the following studied method, this period has varies in times. The studied area; shown in (Figure 2), has one known fixed point (C) it's coordinates are shown in (Table1).

The observation data listed in RINEX file for any observed satellite at each observation epoch are: phase measurements ($L_1$ phase and $L_2$ phase), code pseudorange (C code, $P_1$ code and $P_2$ code) , Doppler shift ($D_1$ and $D_2$) and the important parameters for ionospheric correction (alpha and beta). Where the terms 'alpha' are the coefficients of the cubic equation which represent the magnitude of the time vertical ; and the terms 'beta' are the coefficients of the cubic equation which represent the period of the model [23]. But the used RINEX file version in this research 'RINEX 2.0' does not include these correction parameters, which considered another main problem as it affects the corrected methodology for both the code and phase of measurements, where the ionospheric error cannot be corrected by using any accurate famous ionospheric models, because all of these models depend on the above mentioned correction parameters.

**Note:** The following resultant coordinates from the used method in this research for any unknown point, will be compared with its coordinates resulting from DGPS method.

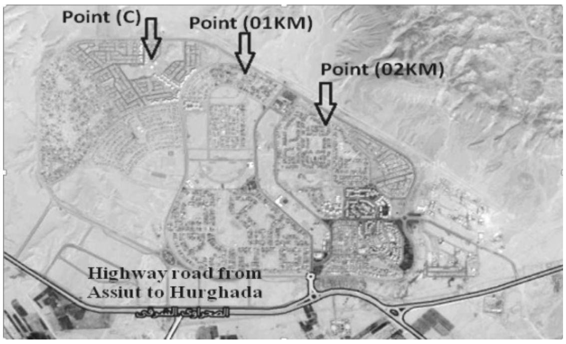


**Figure 2: The Studied Area**

**Table 1: The Coordinates of Fixed Point (C)**

| Co-ordinate frame | Fixed point (C) | | |
|---|---|---|---|
| ECEF frame X,Y , and Z | 4847990.24 | 2944869.45 | 2906897.9 |
| Geodetic frame Lat, long and $h_{elip}$ | 27.2902965 ° N | 31.2762236° E | 128.346 |
| Old Egypt 1906 E,N and $h_{orth}$ | 642190.684 | 509720.116 | 118.699 |

## ADJUSTING PROCESS FOR POSITIONING ACCURACY

The idea of the adjusting process in this research is the using of the differential technique between the observational data from one unit receiver (Rover) and the observational data produced daily from the nearest IGS station (Base) ; in order to obtain high accuracy with vanishing the ambiguity term and reduce or eliminate the ionospheric error. But there is a big problem, because IGS service does not cover our area 'EGYPT'; where the nearest IGS station far away hundred kilometers from EGYPT. So, this research will process the data with specific assumptions and conditions to overcome this problem.

The International GPS Service (IGS) has an international network of over 382 fixed stations around the world (Figure 3) ; which continuously operates dual-frequency GPS stations and daily uploads the produced observational data on the internet website "ftp://cddis.gsfc.nasa.gov/".[24]. The nearest station used in this research is 'called DRAG' located in the West Bank in Palestine beside the Dead Sea, and at distance about 660 km from point (C) in our studied area .

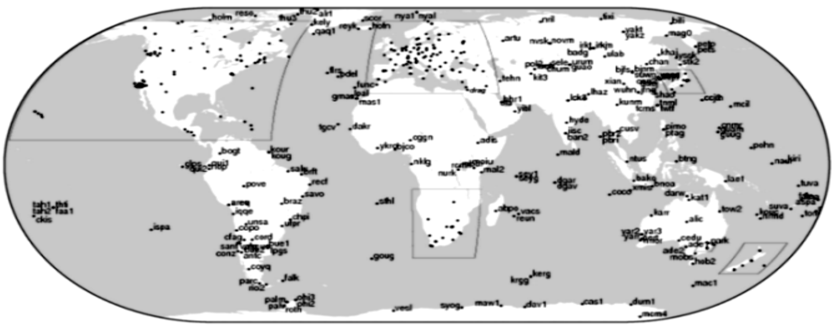

**Figure 3: The Distribution of IGS Stations Around the World**

Firstly; the differential positioning mode between the observations of studied points and the observations of DRAG station is applied, where its results refer to about 2.5 m error (Figure 4). That due to the baseline length which has a high effect on the positioning accuracy, about 5mm error / 1km length [14].

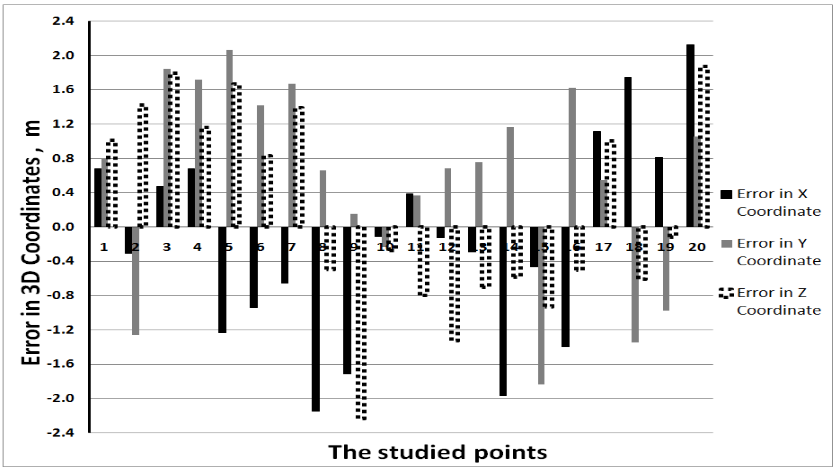


**Figure 4: Errors in 3D Coordinates Resulting from DGPS Mode by Using the Nearest IGS Station ' DRAG'.**

The positioning accuracy is still low as shown in (Figure 4), because the ionospheric and orbital errors have basically increased with the baseline length between the reference and user stations ; so these errors will not be completely eliminated by using the technique of DGPS [25]. Where the ionospheric error is completely eliminated using DGPS method at the baseline up to 20km; but over 20km , the ionospheric disturbance may prevent ambiguity resolution with a single- frequency or even with a dual- frequency. In this case, the double difference technique equations will contain two unknown, which are the integer cycle ambiguity and ionospheric error [26].

To overcome the previous problems and errors due to the baseline lengthens equal 660km, an analyzing method will be done: firstly, using the precise ephemeris data to adjust the orbital errors, as it can be downloaded from IGS website. Also, the effects of orbital errors are usually smaller in size [26]. Secondly, it must solve the observations of a fixed point in studied area relative to the DRAG station using triple difference technique to estimate the ionospheric difference error. The fixed point in studied area must be at distance less than 20 km from the unknown point.

Where at triple difference technique, the given data are two receivers observed two satellites at two constitutive epochs with small interval. As, if the observation epochs interval is small enough (less than 5 sec), all the errors, especially the ionospheric error, might be neglected due to its slight magnitude [27 and 28].

Firstly, When applying the triple difference technique between two receivers, one at the fixed point (C) and the other at DRAG station (D), two satellites are observed (J and K) at two constitutive epochs (i and q) . In (Figure 5), it is found that the final equation (Equ. 3) contains one unknown which is the value of residual ionospheric error.

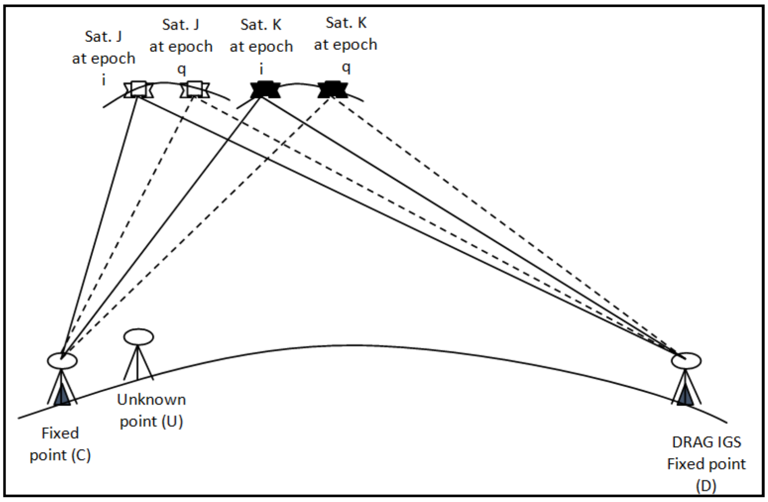


**Figure 5: Triple Difference (TD) between Two Receiver at the Fixed Point in Studied Area (C) and DRAG Station (D)**

$$\lambda_{Li}({\emptyset_{Li}}_D^{K^q} - {\emptyset_{Li}}_C^{K^q} - {\emptyset_{Li}}_D^{J^q} + {\emptyset_{Li}}_C^{J^q} - {\emptyset_{Li}}_D^{K^i} + {\emptyset_{Li}}_C^{K^i} + {\emptyset_{Li}}_D^{J^i} - {\emptyset_{Li}}_C^{J^i}) = (\rho_D^{K^q} - \rho_C^{K^q} - \rho_D^{J^q} + \rho_C^{J^q} - \rho_D^{K^i} + \rho_C^{K^i} + \rho_D^{J^i} - \rho_C^{J^i}) - (I_D^{K^q} - I_C^{K^q} - I_D^{J^q} + I_C^{J^q} - I_D^{K^i} + I_C^{K^i} + I_D^{J^i} - I_C^{J^i}). \quad \textbf{(3)}$$

Where $\phi$ is the measured phase obtained from observation RINEX file (cycle) ; **Li** is the phase type $L_1$ or $L_2$ ; $\rho$ is the true geometric distance between the receiver and the satellite (m) ; **I** is the ionospheric error (m) [29].

The previous equation can be written in the following form (Equ. 4):

$$\delta\nabla\Delta{\emptyset_{Li}}_{D,C}^{K,J}(i,q) = \delta\nabla\Delta\rho_{D,C}^{K,J}(i,q) - \delta\nabla\Delta I_{D,C}^{K,J}(i,q) \quad \textbf{(4)}$$

Where $\nabla\Delta$ and $\delta\nabla\Delta$ are the double difference and triple difference which operate respectively, and the $\boldsymbol{\delta\nabla\Delta I_{D,C}^{K,J}(i,\ q)}$ means the change in the residual ionospheric error between two receivers (D and C), and two satellites (J and K), at two constitutive epochs (i and q).

The $\delta\nabla\Delta I_{D,C}^{K,J}(i,\ q)$ in (Equ.4) can be estimated, when it is substituted in this equation by the measured values of the phase ($\phi$) and the accurate geometric distance values ($\rho$). Where $\rho$ value can be estimated from the known coordinates of fixed point and DRAG station, and the accurate coordinates of satellites obtained from the precise ephemeris data (sp3 files).

Secondly; When applying the triple difference technique between two receivers at the unknown point (U) and DRAG station (D), two satellites are observed (J and K) at two constitutive epochs (i and q) , as shown in (Figure 6). The value of $\delta\nabla\Delta I$ will be found also at the final triple difference equation (Equ.5 and Equ.6) due to the large baseline between two points, which is about 660km.

From previously mentioned information; if the epochs interval is smaller than 5 sec, then the value of $\delta\nabla\Delta I_{D,C}^{K,J}(i,\ q)$ might be neglected. But the observations RINEX files for any IGS station; which downloaded from IGS service web, have an observation epoch interval 15 second, therefore this term might be has an effective value.

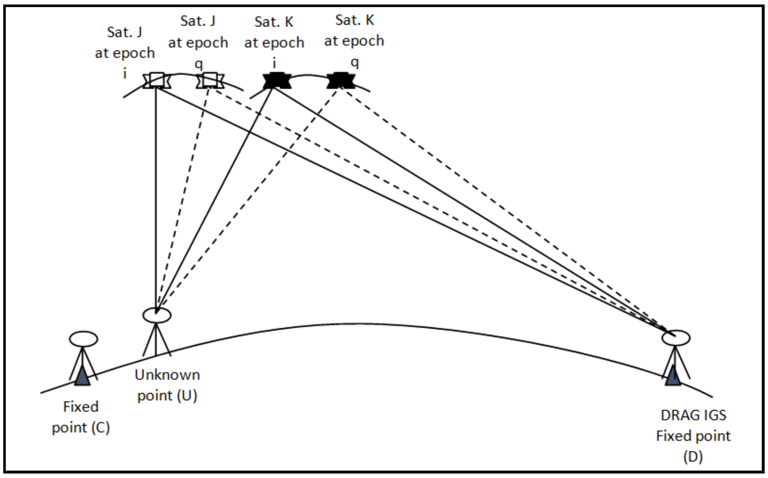


**Figure 6: Triple Difference (TD) between Two Receiver at the Unknown Point in Studied Area (U) and DRAG Station (D)**

$$\lambda_{Li}({\emptyset_{Li}}_D^{K^q} - {\emptyset_{Li}}_U^{K^q} - {\emptyset_{Li}}_D^{J^q} + {\emptyset_{Li}}_U^{J^q} - {\emptyset_{Li}}_D^{K^i} + {\emptyset_{Li}}_U^{K^i} + {\emptyset_{Li}}_D^{J^i} - {\emptyset_{Li}}_{CU}^{J^i}) = (\rho_D^{K^q} - \rho_U^{K^q} - \rho_D^{J^q} + \rho_U^{J^q} - \rho_D^{K^i} + \rho_U^{K^i} + \rho_D^{J^i} - \rho_U^{J^i}) - (I_D^{K^q} - I_U^{K^q} - I_D^{J^q} + I_U^{J^q} - I_D^{K^i} + I_U^{K^i} + I_D^{J^i} - I_U^{J^i}) \quad \mathbf{(5)}$$

Or

$$\delta\nabla\Delta{\emptyset_{Li}}_{D,U}^{K,J}(i,q) = \delta\nabla\Delta\rho_{D,U}^{K,J}(i,\ q) - \delta\nabla\Delta I_{D,U}^{K,J}(i,q) \quad \mathbf{(6)}$$

The assumption in this method is that: the estimated value of $\delta\nabla\Delta I_{D,C}^{K,J}(i,\ q)$ between the two fixed points (fixed and DRAG) equals the unknown value of $\delta\nabla\Delta I_{D,U}^{K,J}(i,\ q)$ between the unknown point and DRAG station, because of the two following reasons:

- If we assume a triple difference technique which is applied between the fixed point in the studied area and the unknown point at a distance less than 20 Km, the final equation will be free from the ionospheric error ($\delta\nabla\Delta I$). So, the estimated value of $\delta\nabla\Delta I_{D,C}^{K,J}(i,\ q)$ from applying the triple difference between the DRAG station and the fixed point (C) in the studied area is the same for any point at a distance less than 20km from the fixed point (C).
- Although the differential process between the unknown point and DRAG station will be done at epochs after the used epochs for applying the differential process between the fixed point and DRAG station, in condition of using the same pairs of satellites at the two processes. But, due to the slight change in magnitude of ionospheric error; the values of $\delta\nabla\Delta I$ are approximately the same at the two differential processes.

The results of this method shown in (Figure 7) refer to an improvement in the coordinates, where the resultant errors in 3D coordinates are about 30 cm, in condition of the distance between fixed and unknown points is up to 20km.

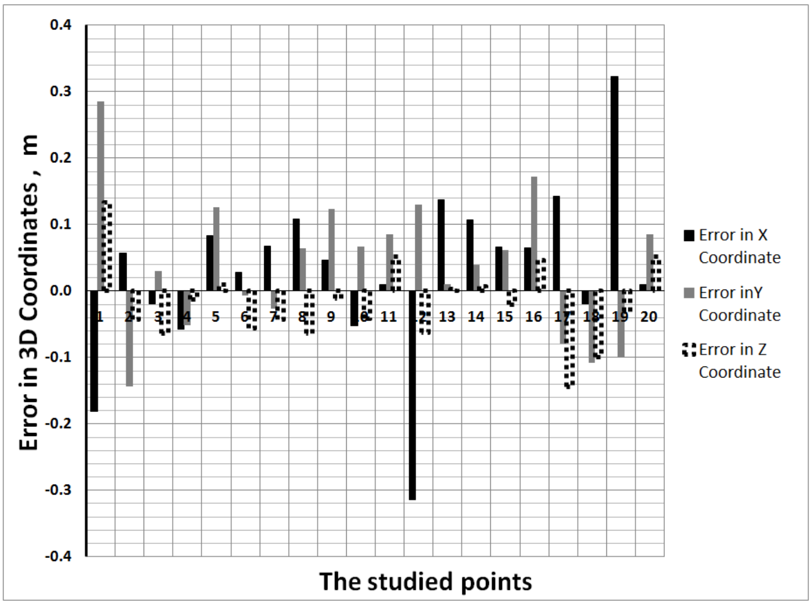


**Figure 7: Errors in 3D Coordinates Resulting from the Used Adjusting Process**

For testing the valid period between observing the unknown points after observing the fixed point, the unknown points will be observed at different times from observing the fixed point (Figure 8).

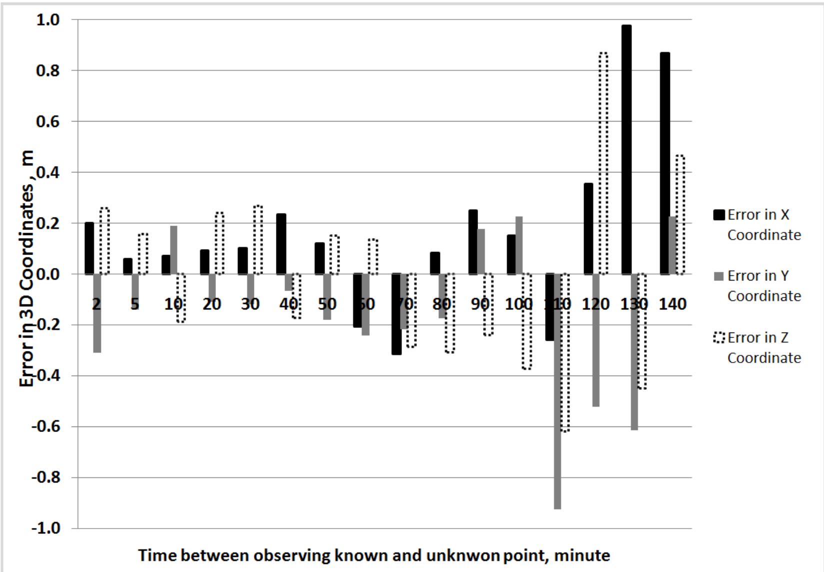


**Figure 8: Errors in 3D Coordinates Resulting from the Used Adjusting Process at Different Times between Observing the Fixed and Unknown Point**

The results refer to that this method is valid for 100 min, as the interval period between observing the fixed and unknown point, where the accuracy is still about 30 cm for this period and reaches 1 m for 140 minute.

## CONCLUSIONS

The adjusting process used in this research had been enhanced to improve the positioning accuracy, which was about 30 cm. In condition that there is one fixed point at least in the observation area, the unknown point at 20 km distance rounded the fixed point, and the interval period between observing the fixed and unknown point is less than 100 min.

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